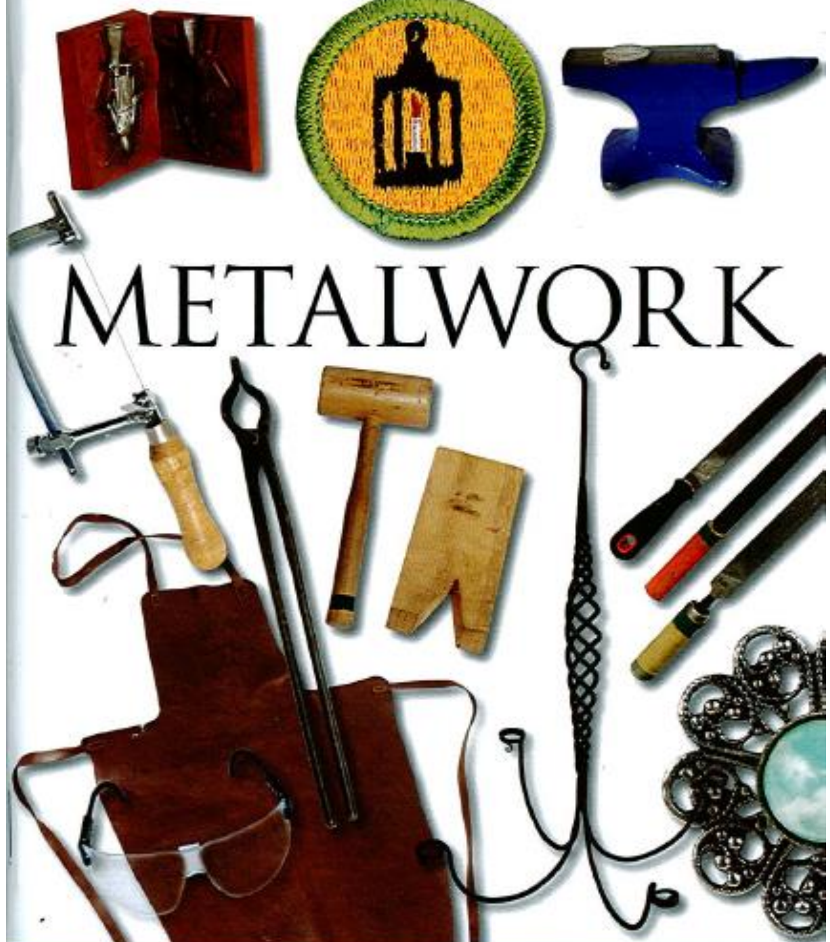
MERIT BADGE SERIES

METALWORK



BOY SCOUTS OF AMERICA.

Note to the Counselor

The Metalwork merit badge offers Boy Scouts a fun way to explore four metalworking disciplines. The four options in this pamphlet were selected because they can be offered at any Boy Scout summer camp that schedules five two-hour sessions for this merit badge.

There is no need to make all four metalworking options available during a Scout's summer camp experience. If finding a counselor for each of the options proves to be too difficult, or if providing all of the tools and materials is too costly, select one option and do it well.

The projects in this pamphlet are offered as guidelines only. If you have favorite projects that can be readily completed by Scouts, feel free to use them. You are encouraged to help enrich each Scout's experience by drawing upon your professional knowledge and experience, but remember that a merit badge counselor may neither add nor delete requirements, nor simplify or make requirements more difficult than stated.

Scouts working on this merit badge require direct adult supervision. A sheet metal burr can cause a cut, molten pewter and orange-hot steel can cause severe burns, and the sulfuric acid silversmiths use to pickle their silver can be dangerous to anyone if used improperly. Work in groups no larger than two to three Scouts per merit badge counselor.

Some of the tools described in this pamphlet are those collected by professional metalworkers throughout their years of experience. Many metalworking professionals continue to practice their trade with a minimal use of power tools. To earn this merit badge, Scouts need learn to use only a few basic tools that they should be able to borrow from a more experienced metalworker. If a Scout develops greater interest in the craft and desires to further the hobby outside the requirements of the Metalwork merit badge, he can begin to collect his own set of tools.

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Requirements

1. Read the safety rules for metalwork. Discuss how to be safe while working with metal. Discuss with your counselor the additional safety rules that apply to the metalwork option you choose for requirement 5.
2. Define the terms native metal, malleable, metallurgy, alloy, nonferrous, and ferrous. Then do the following:
   a. Name two nonferrous alloys used by pre–Iron Age metalworkers. Name the metals that are combined to form these alloys.
   b. Name three ferrous alloys used by modern metalworkers.
   c. Describe how to work-harden a metal.
   d. Describe how to anneal a nonferrous and a ferrous metal.
3. Do the following:
   a. Work-harden a piece of 26- or 28-gauge sheet brass or sheet copper. Put a 45-degree bend in the metal, then heavily peen the area along the bend line to work-harden it. Note the amount of effort that is required to overcome the yield point in this unworked piece of metal.
   b. Soften the work-hardened piece from requirement 3a by annealing it, and then try to remove the 45-degree bend. Note the amount of effort that is required to overcome the yield point.
   c. Make a temper color index from a flat piece of steel. Using hand tools, make and temper a center punch of medium-carbon or high-carbon steel.

4. Find out about three career opportunities in metalworking. Pick one and find out the education, training, and experience required for this profession. Discuss this with your counselor, and explain why this profession might interest you.
5. After completing the first four requirements, complete at least ONE of the options listed below.

a. Option 1—Sheet Metal Mechanic/Tinsmith

1) Name and describe the use of the basic sheet metalworking tools.
2) Create a sketch of two objects to make from sheet metal. Include each component's dimensions on your sketch, which need not be to scale.
3) Make two objects out of 24- or 26-gauge sheet metal. Use patterns either provided by your counselor or made by you and approved by your counselor. Construct these objects using a metal that is appropriate to the object's ultimate purpose, and using cutting, bending, edging, and either soldering or brazing.
   a) One object also must include at least one riveted component.
   b) If you do not make your objects from zinc-plated sheet steel or tin-plated sheet steel, preserve your work from oxidation.

b. Option 2—Silversmith

1) Name and describe the use of a silversmith's basic tools.
2) Create a sketch of two objects to make from sheet silver. Include each component's dimensions on your sketch, which need not be to scale.
3) Make two objects out of 18- or 20-gauge sheet copper. Use patterns either provided by your counselor or made by you and approved by your counselor. Both objects must include a soldered joint. If you have prior silversmithing experience, you may substitute sterling silver, nickel silver, or lead-free pewter.
   a) At least one object must include a sawed component you have made yourself.
   b) At least one object must include a sunken part you have made yourself.
   c) Clean and polish your objects.

c. Option 3—Founder

1) Name and describe the use of the basic parts of a two-piece mold. Name at least three different types of molds.
2) Create a sketch of two objects to cast in metal. Include each component's dimensions on your sketch, which need not be to scale.
3) Make two molds, one using a pattern provided by your counselor and another one you have made yourself that has been approved by your counselor. Position the pouring gate and vents yourself. *Do note use copyrighted materials as patterns.*
   a) Using lead-free pewter, make a casting using a mold provided by your counselor.
   b) Using lead-free pewter, make a casting using the mold that you have made.

d. Option 4—Blacksmith

1) Name and describe the use of a blacksmith's basic tools.
2) Make a sketch of two objects to hot-forge. Include each component's dimensions on your sketch, which need not be to scale.
3) Using low-carbon steel at least ¼ inch thick, perform the following exercises:
   a) Draw out by forging a taper.
   b) Use the horn of the anvil by forging a U-shaped bend.
   c) Form a decorative twist in a piece of square steel.
   d) Use the edge of the anvil to bend metal by forging an L-shaped bend.
4) Using low-carbon steel at least ¼ inch thick, make the two objects you sketched that require hot-forging. Be sure you have your counselor's approval before you begin.
   a) Include a decorative twist on one object.
   b) Include a hammer-riveted joint in one object.
   c) Preserve your work from oxidation.

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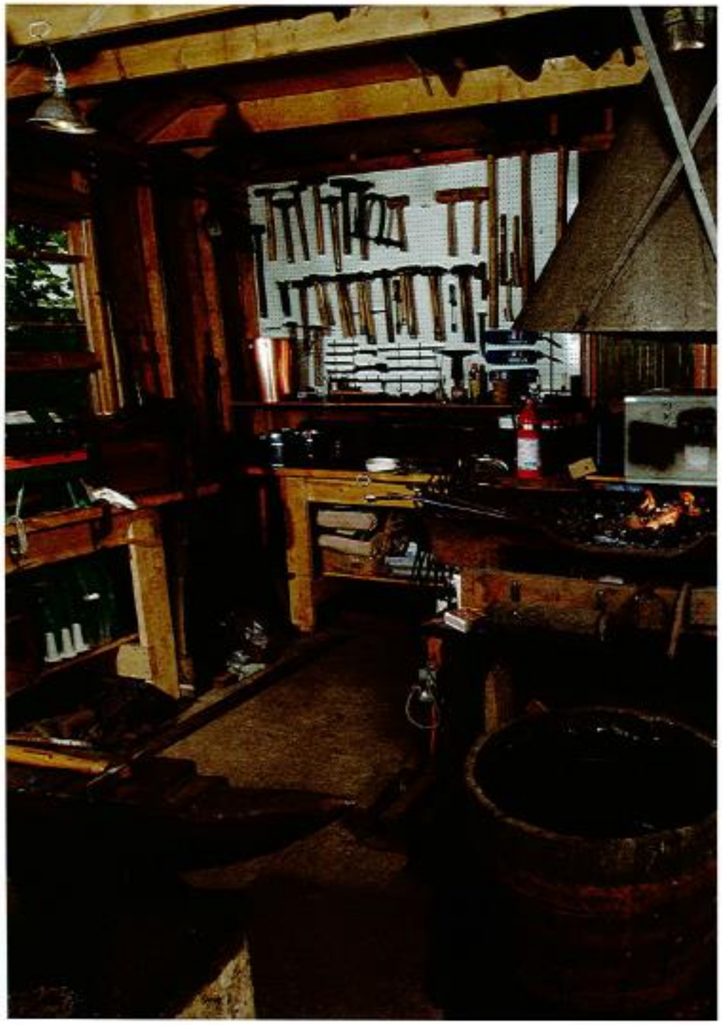
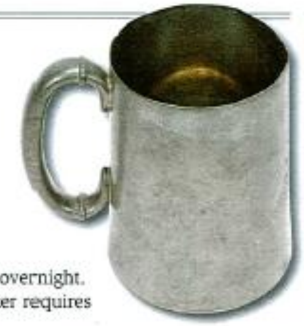




Introduction

Mastering the metalworker's craft cannot happen overnight. Learning the skills and techniques of a metalworker requires knowledge of the basics—and lots of practice.

You will begin your work on this merit badge by learning about the properties of *metal*, how to use simple metalworking tools, and the basic metalworking techniques. Then you will practice using these tools and techniques before concentrating on the more intricate skills of one of the four metalworking options offered for the Metalwork merit badge:

- Sheet metal mechanic/tinsmith
- Silversmith
- Founder
- Blacksmith

Sheet metal mechanics, or tinsmiths, work by bending thin sheets of metal then *soldering* the component parts together. Silversmiths hammer and cut thin sheets of metal into gracefully shaped components and then solder the parts together. Founders pour molten metal into molds to make a finished piece. Blacksmiths use fire, water, and *steel* to hammer out fanciful and useful objects. All four of these metalworking techniques can create art objects of great beauty as well as useful objects that meet a practical need. The choice is yours!

The History of Metal

Anatolia is a region in modern-day Turkey.

Working metal is one of humankind's oldest skills. When prehistoric people discovered metal in its natural state and then found that they could change its shape by hitting it with a hammer, they became the world's first metalsmiths.

The Copper Age

During the late Stone Age, between 7000 B.C. and 6000 B.C., scientists believe humans in Anatolia learned to create useful items from *native* copper they had found. *Native metals* are those that occur naturally in a nearly pure form. Copper is a *nonferrous* metal—one that does not contain iron—that occasionally can be found in a native state. Other nonferrous metals that occur naturally are gold, silver, and tin.

Native copper

About a thousand years later, scientists say, our ancestors began to melt native metals. Placing the lumps of metal in a *crucible*, a container that resists high heat, they would melt the metal and then pour a stream of molten metal into crude two-piece clay molds.

ORE-BEARING ROCKS

Trade values increased the demand for metal objects and forced early metalworkers to look for additional sources of metal. They found one solution in *ore-bearing rocks*.

It is unknown how our ancestors discovered that certain rocks leave a small amount of metal behind when they are melted in extremely hot fires. Today, this process—called *smelting*—is a large part of the metal industry. Smelting iron from ore probably began in China and India around 4000 B.C. and then spread westward to the area around the Black Sea.

Yet another important discovery of this era was the creation of *alloys*—metals mixed with other metals or substances to change the properties of the metal. Silversmiths began to add a small amount of copper to silver, and goldsmiths began to add small amounts of silver and copper to gold, which reduced the *ductility* of these two very soft metals, making them less likely to deform—and much more useful.

Ore-laden rock

The Bronze Age

The Bronze Age began in China around 3300 B.C., when smiths began creating tools with a strong alloy made by adding tin to copper. The result was bronze—a metal with such reduced ductility that it could be fashioned into tools strong enough to cut blocks of limestone and granite. By 2500 B.C., the technique had spread throughout India and to the eastern Mediterranean countries.

Copper ingot, Bronze Age, Greece

CASTING EMERGES

Throughout the early ages of metalworking, smiths could create objects by heating metal and hammering it on an *anvil*. As their knowledge of metal increased, they found that molten metal could be *cast* into a hollow mold.

Initially, molds were made of clay. As metalworkers in countries in eastern India, China, and along the Mediterranean Sea developed their casting skills, better types of molds emerged. Some types of molds, including hard-packed sand molds and ceramic molds, are still being used.

The Iron Age

Soon after people discovered that they could smelt ores, the production of iron began. Because iron ore is more abundant than copper ore, iron can be produced in larger quantities and at lower cost than copper. Smiths began to create iron pieces such as cooking kettles, which quickly became popular because of their availability and usefulness.

Because of its low production cost and high demand, iron became known as the "democratic" metal.

The Discovery of Steel

Metalworkers in India and Japan independently discovered how to make steel in about A.D. 600. To create this strong alloy, iron and carbonaceous material (charcoal, sawdust, or other matter that contains the element carbon) were mixed in a crucible and heated in a *forced-draft* furnace long enough for the iron pieces to melt and absorb the carbon gas produced by the carbonaceous matter. The result was a steel disk, called a cake, which blacksmiths then forged into bars that could be used as trade goods.

Because steel is less ductile and *malleable*—capable of being shaped with tools—than iron, a blacksmith has to work harder to make something out of steel than out of iron. Objects made of steel are much less likely to bend or deform than items made of iron, and by controlling the amount of carbon introduced during the production stage, steels of varying *hardness* can be manufactured.

The drawbacks to making something from high-carbon steel are lost flexibility and the chance that the item may snap if twisted.

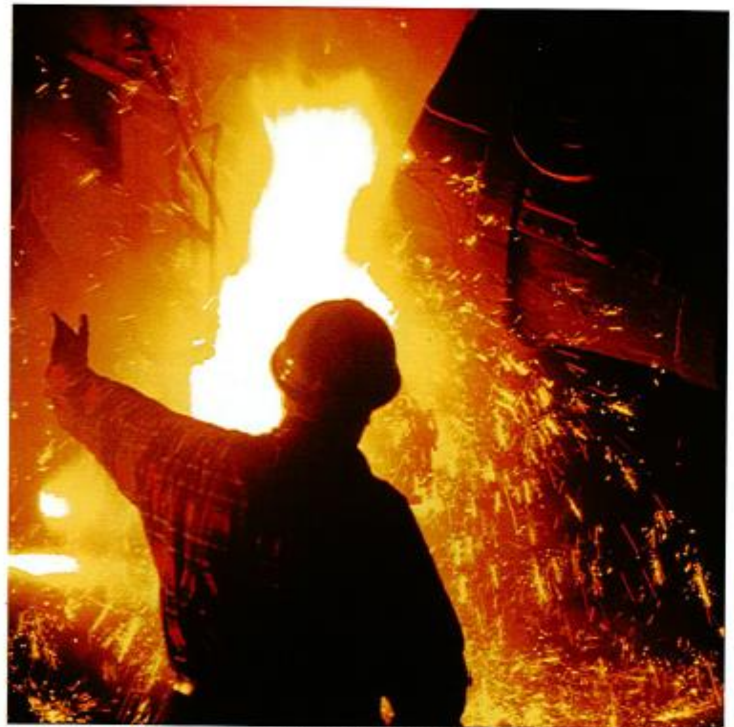
CARBON STEELS

Steel is iron that contains less than 2 percent carbon. Low-carbon steel contains up to 0.25 percent carbon. Medium-carbon steel contains between 0.25 and 0.55 percent carbon. High-carbon steel contains more than 0.55 percent carbon, but today's usual upper limit is about 1.20 percent carbon. Carbon steels contain iron as the only metal in their composition.

The steel that is most often used by today's blacksmiths and sheet metal mechanics contains between 0.08 to 0.23 percent carbon. Modern industry uses one of the medium-carbon steels to make most hand tools. If an item must hold a sharp edge for a long time, such as a pocketknife or an ax, then one of the high-carbon steels is used.

ALLOY STEELS, STAINLESS STEELS, AND BEYOND

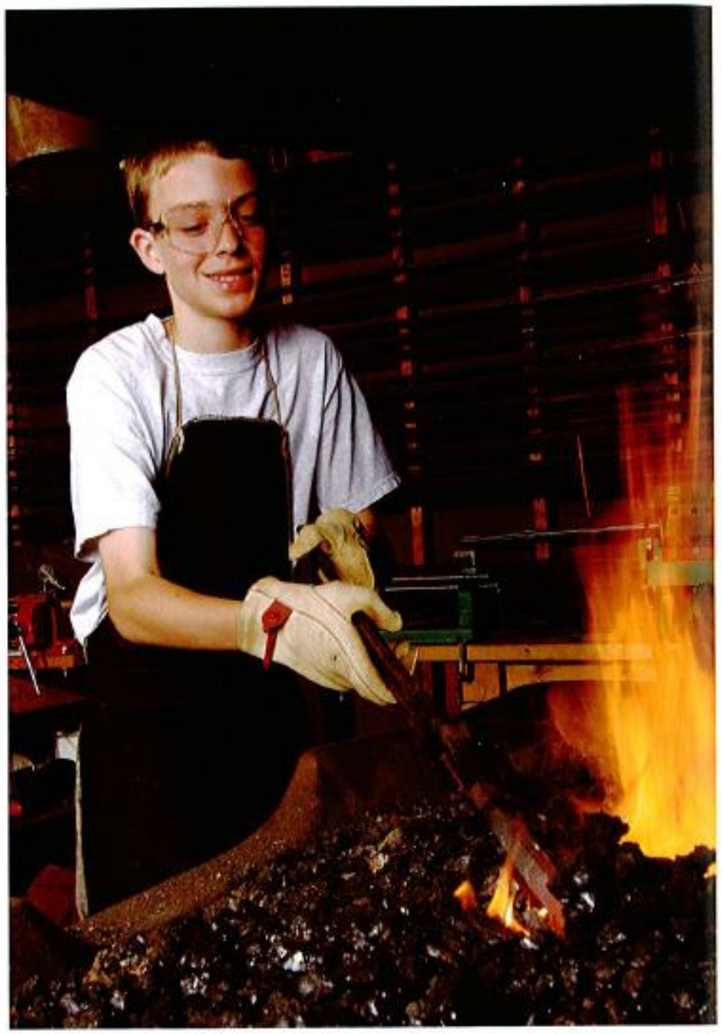
Until the invention of the steam engine, wrought iron and carbon steel served quite well. As the use of steam-powered machinery caught on with industry during the 19th century, each new steam engine model produced greater power. These increasingly more powerful engines placed more demands upon their metal components, so the engineers who designed steam engines began to demand stronger and tougher new alloys, especially *ferrous* alloys. They turned to *metallurgists*—scientists who study the properties of metals—to help meet their demands.



Modern steel companies produce an average of 200 to 300 different steel grades to meet the industry's demands.

The metallurgists experimented by adding small amounts of other metals to carbon steel, creating alloy steels that were increasingly more ductile, stronger, harder, tougher, and more resistant to wear and *corrosion*.

Rising demands by industrial steel consumers, such as the producers of automobiles and manufacturing equipment, have led to the development of many new varieties of steel.



The Basics of Metalworking

Metalworking requires the craftsman to pay close attention to the work at hand and to adhere closely to special safety requirements. Before diving into the techniques of metalworking, learn how to keep yourself and others safe while working with metal.

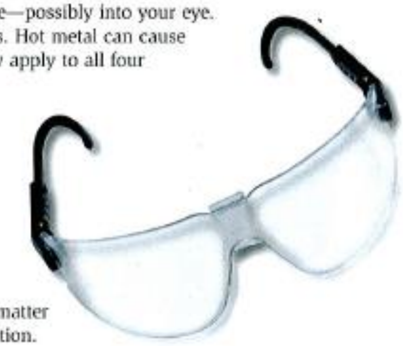
Safety Rules

When working with metal, acid, and high temperatures, metalworkers should be aware of possible hazards, and youths must have adult supervision. Following the rules will keep metalworking safe and enjoyable.

Sheet Metal Safety

Paying attention to what you are doing and wearing the proper gear is critical in metalworking. When sheet metal is cut, a small chip of metal can fly anywhere—possibly into your eye. Sharp edges on metal can cause cuts. Hot metal can cause painful burns. The rules listed below apply to all four metalworking options.

1. Always work with direct adult supervision.
2. Always wear safety goggles or safety glasses, leather gloves, and a shop apron.
3. Handle sheet metal with care. It can cause serious cuts.
4. Treat every cut immediately, no matter how minor, to help prevent infection.



Safety glasses

5. Remove all burrs from the sheet metal before attempting further work on it.
6. Do not run your hands over the surface of sheet metal that has just been cut or drilled. The burrs can cut.
7. Use a brush—not your hands—to clean the work area.
8. Place scrap pieces of sheet metal in a scrap box right away.
9. Do not use tools that are not in top condition. Avoid using hammers with loose handles or chisels with worn or misshapen heads.
10. Use a broom and a dustpan to sweep the shop floor. Do not leave slivers of metal on the worktable or the shop floor.

Always wear the proper safety gear when working with metal.

Safety With the Pickling Tank

If you select the silversmith option to complete your Metalwork merit badge, you have additional safety rules to learn. Follow these guidelines when using the *pickling tank*, an integral step in the silversmithing process.

1. Always use the pickling tank with adult supervision.
2. Always wear eye protection, a shop apron, and rubber gloves when working with the pickling tank and solution. Use tongs to move items into and out of the pickling solution.
3. Use the pickling tank in a well-ventilated space, and do not breathe fumes from the pickling solution.
4. Never pour water into the pickling tank solution; pour the pickling solution into the water.
5. Keep small children and pets away from the pickling tank.
6. Always store the pickling tank with its lid tightly secured.
7. Plainly mark the contents of the pickling tank.

Safety With Molten Pewter

If you select the founder option to complete your Metalwork merit badge, you will be working with molten pewter. You must know a few more safety rules:

1. Always work with direct adult supervision.
2. Have a fire extinguisher handy when using the *melting pot.*
3. Place a sheet of metal under the melting pot and the mold-pouring area to prevent accidental splatters from burning your worktable.
4. Wear safety glasses, leather gloves, long pants, boots, and a shop apron when pouring metal. Be sure to pull your pant legs down over the top of your boots. Do not wear shorts, sandals, or water shoes.
5. Do not set a pouring ladle down with its handle extending past the edge of the workbench.
6. Do not put moist or wet metal in the melting pot. Bubbles caused by escaping steam will cause the molten metal to splash out of the crucible, possibly causing painful burns.
7. Do not eat while casting metal.
8. Always wash your hands after handling metal.

Safety With Hot Steel

If you choose the blacksmith option to complete your Metalwork merit badge, you will be working with orange- or yellow-hot steel. Here are some special rules that you must follow:

1. Always work with direct adult supervision.
2. Have a fire extinguisher handy at all times.
3. Wear safety glasses, leather gloves, a shop apron, long pants, and boots when working in a blacksmith shop. Be sure to pull your pant legs down over the tops of your boots. Do not wear shorts, sandals, or water shoes.
4. Allow hot metal to cool in an out-of-the-way place.
5. Use tongs to pick up a dropped object. Although it might not glow, the metal might still be 1000 degrees.

Tools and Materials

The following tools and materials can be used to learn the techniques and complete the projects described in this pamphlet. The basic techniques are explained in this chapter, and step-by-step instructions for the projects are given in later chapters.

Tools

- ❑ Sheet metal snips
- ❑ Patterns
- ❑ Machinist's vise
- ❑ Center punch
- ❑ Flat-faced wooden mallet
- ❑ Pipe anvil
- ❑ Iron pipe of about 2-inch outside diameter
- ❑ Hand seamer
- ❑ Hemmer
- ❑ Lineman's, needle-nosed, and locking-jaw pliers
- ❑ Wood blocks, in pairs
- ❑ Two C-clamps
- ❑ Flat file with handle
- ❑ 12-ounce ball peen hammer
- ❑ ½-inch cold chisel
- ❑ Hacksaw and spare blades
- ❑ Pop rivet gun
- ❑ Rivet set
- ❑ Propane torch
- ❑ 125-watt or 150-watt electric soldering iron
- ❑ Steel dividers
- ❑ Folding rule or measuring tape
- ❑ Carpenter's square (or equivalent)
- ❑ Metal straightedge
- ❑ Scriber
- ❑ Drill press
- ❑ Drill bits (sized to match the pop rivets)
- ❑ Shop apron
- ❑ Leather gloves
- ❑ Safety glasses

Materials

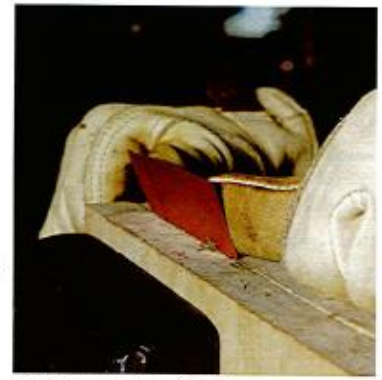
- ❑ Lead-free solder
- ❑ Variety of family-size metal food cans (avoid institutional-size food cans; they are too large to make the projects in this pamphlet)
- ❑ Two or three tenpenny nails
- ❑ Two or three pop rivets
- ❑ Two 3-by-3-inch pieces of 26- or 28-gauge copper or brass (not steel or aluminum)
- ❑ One 5-inch piece of $\frac{3}{8}$-inch (round or square) medium-carbon or high-carbon steel (C1065, W1, or equivalent)
- ❑ Clothes hanger wire
- ❑ Five or six small blocks of scrap 2-by-4-inch lumber of different lengths
- ❑ One 6-inch flat steel scrap
- ❑ Soapstone pencil

Mark your tools with tape, paint, or permanent markers so that you can identify them easily in the shop.

Springback

Cold metal does not always stay in place after it is bent. To overcome the *springback* effect, the metal often must be bent past its *yield point.*

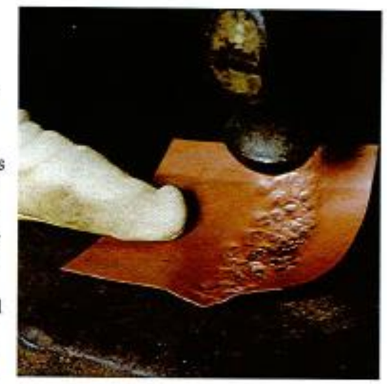
An experiment will demonstrate springback. Place a thin piece of sheet brass or sheet copper that has never been worked between two pieces of wood, leaving enough metal clear of the top so you can press against it with your hand. Clamp the wood and metal tightly into a vise. Without using any tools, do your best to put a 45-degree bend in the unworked metal. Stop when you have pushed the metal to 45 degrees. *Do not overbend the metal.* When you let go, the angle of the metal will adjust itself to something less than 45 degrees. That effect is springback.



To demonstrate springback, use your hands to push the unworked metal into a 45-degree angle.

Work Hardening

The process of hardening a metal by hammering it is called *work hardening.* All metals except mercury and lead become harder as they are hammered. As a metal is work-hardened, it becomes more resistant to change its shape. The metal must be softened—or *annealed*—from time to time during the work hardening process or it will rupture or crack.



Another experiment provides an example of work hardening. Hit a small piece of thin sheet brass or sheet copper repeatedly with the domed end of a ball peen hammer. Place your blows closely together, covering the work with small dents. This peening process causes the *crystals* that form the metal to condense with each blow. The closer the crystals are to each other, the stiffer the metal becomes.

Annealing

Metal is *annealed* by heating it to the temperature where it is soft enough for the metalworker to continue to shape the piece. How long a piece of metal is exposed to the critical temperature depends on its thickness and shape.

Most irons and steels are ferrous. Some nonferrous metals are aluminum, tin, copper, brass, silver, gold, and platinum.

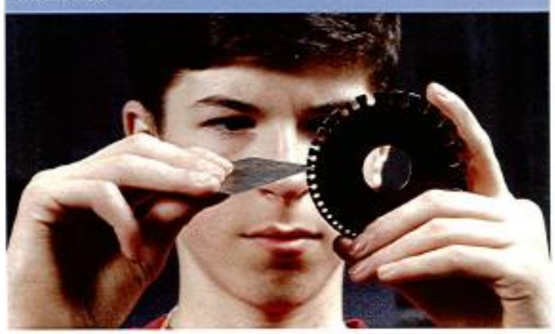
Annealing Ferrous Metals

Most ferrous alloys must be cooled slowly after being elevated to their critical temperature. When high-carbon steel is cooled too quickly, it becomes brittle and tends to crack easily. This is referred to as being glass hard.

High-carbon steel is annealed by being heated to a bright cherry red heat (about 1350 degrees) and then being cooled slowly in a metal box insulated with wood ashes or vermiculite (clean cat litter). The piece must be cooled for at least eight hours before it is worked again.

Measuring the Thickness of Metal

In the United States, the thickness of sheet metal and wire is measured with a thickness gauge—one for ferrous metal and another for nonferrous metal. The system runs from 0—about the diameter of a pencil—to 36—finer than a human hair. The numbers run consecutively, although even-numbered gauges are used most often. Twenty-gauge sheet steel is 0.035 inch thick, while 20-gauge nonferrous metal is 0.032 inch thick.



Annealing Nonferrous Metals

Nonferrous metals are annealed by bringing them to a cherry red heat, allowing them to cool until the color disappears, and then *quenching* them in a pickling solution. For copper, brass, and silver, cherry red heat ranges from 660 degrees to 1100 degrees, depending on the alloy. Unlike ferrous metals, nonferrous metals do not become brittle if cooled immediately after reaching critical temperature. This permits a metalworker to quickly continue working.

Riveting

A *rivet* is a mechanical fastener that is hammered into place. Factory-made rivets are available in a variety of sizes. Common nails can be used as rivets if they are cut to the correct length and the shank is peened down. While the nail head is flat instead of round like a rivet, it will hold adequately.

Soldering and Brazing

Soldering and *brazing* are methods of joining metals with melting nonferrous metal filler without having to heat the base metal to its *melting point*. The method used depends on the metals involved in projects.

Use only lead-free solder. Although lead-tin solder is still available, it releases toxic fumes. Over time, inhaling these fumes can cause brain damage. Eating or drinking from utensils made of lead-tin solder also can cause brain damage.

Before two metals can be joined by soldering or brazing:

1. The surfaces to be soldered or brazed must be clean.
2. An adequate source of heat must be available.
3. The correct solder or brazing alloy must be used.
4. The proper *flux* must be applied.

Solder

Solder is a metal filler that is melted to join two pieces of metal. By definition, soldering occurs at temperatures less than an arbitrary 800 degrees. Use lead-free solder when joining tin-plated steel and thin sheet steel.

Silver Solder

Silver solders are brazing materials that melt at temperatures higher than 800 degrees. When working with silver, always use silver solder rather than regular solder. Silver solder can be made to flow using a propane torch.

There are five categories of silver solder.

Type of Solder	Flow Temperature
Extra-easy-flow silver	1200 degrees
Easy-flow silver	1300 degrees
Medium-flow silver	1360 degrees
Hard-flow silver	1460 degrees
IT silver (high-temperature solder)	1490 degrees

Having all five types of silver solder handy is smart when assembling pieces of a complex project. The first solder joint should use the highest-temperature silver solder available. Subsequent joints should use the remaining solders in declining temperature order as the subsequent components are attached. This way the first joint will not come apart as the next joints are soldered.

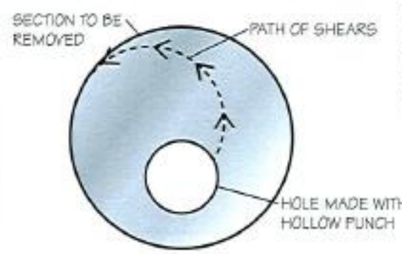
Flux

All metals oxidize when exposed to air, especially humid air. The thin layer of tarnish or rust that results must be removed before solder will stick to a metal. A chemical mixture called *flux* is applied to the joint to remove these oxides and prevent further oxidizing while the metal is heated to the soldering temperature. Flux also lowers the surface tension of the molten solder, making it flow more easily.

When using an acid flux, wear gloves and goggles, and work in an area with good ventilation.

Cutting

Use handheld sheet metal shears to make projects. These shears are manufactured with right-cutting, left-cutting, and combination jaws. Hold the shear and look down the blade to determine which kind of shear you have. If the blade curves to the right, it is a right-cutting shear. If the blade curves to the left, it is a left-cutting shear. If the blade does not curve at all, it is a combination shear that can be used to make straight as well as circular cuts.



To cut a hole in sheet metal, first use a hollow punch to make a small hole inside the diameter of what will become the large hole. Then insert the tip of the snips into the punched hole. Cut in a circular pattern until the layout line is reached. Follow the layout line to complete the cut.

Edging

The small band of metal that runs around the top edge of a modern metal can is a machine-made *hem*, or a safe edge. Because a cut edge is too sharp to be left in a finished piece, a careful sheet metal mechanic will put a hem in the edge for safety.

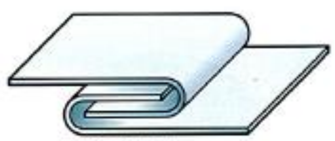
Use a hand seamer to make bends. To bend a safe edge, place 3/16 inch of metal in the seamer's jaws.

Bending

A bar former is used to make bends in small sheet metal sections, and a bending break is used to make bends in large sheet metal sections. Both tools can be set up to make 90-degree and 45-degree angles as well as curved bends. If there is no access to a bar former or a bending break, clamp sheet metal between two wooden blocks or between two steel bars and use a wooden *mallet* to make the bend. Or, if your projects are small, use a hand seamer to make bends.

Seaming

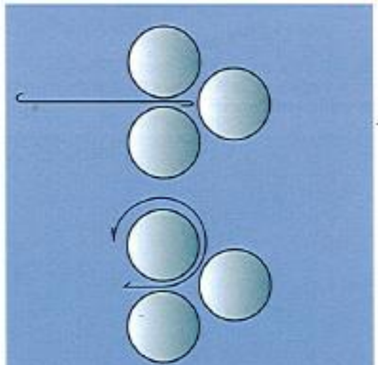
Seaming is the process of joining two pieces of metal as if by sewing. The flatlock seam is most commonly used when making an item from sheet metal. When designing a piece, allow for extra metal on the edges to make the seams.



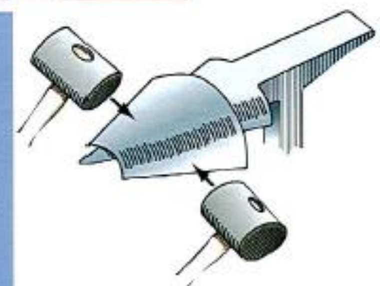
Flatlock seam

Rolling

Rolling is a technique that allows the metalworker to create rounded shapes easily. A slip-form roller can be used to shape sheet metal into a cylinder. Using a mallet, you can also gently hammer the metal over the edges of an anvil or over a piece of iron pipe.



A slip-form roller can be used to make curved shapes such as cones and cylinders. Notice in the diagram that the edges of the seams have already been bent and are facing opposite directions.



When using the horn of the anvil to roll sheet metal, do not hit straight down on the metal where it touches the anvil. Position the blows to avoid denting and crimping the sheet metal.

Tempering

Unlike iron, steel can be hardened to the point that it becomes brittle and fractures easily. To make it useful, its brittleness must be relaxed enough to make the steel capable of holding an edge without snapping when flexed. This relaxing technique is called *tempering*.

Tempering is done in two steps. First, the steel is made brittle by being heated to its critical temperature (between 1350 and 2400 degrees, depending on the alloy and the carbon content) and then being cooled rapidly by plunging into a pickling bath or water, depending on the metal.

The second step is the real tempering step. The brittleness is relaxed by applying just the right amount of heat to achieve the correct degree of hardness needed to make the tool function properly. A temper color index will help determine the degree of hardness desired.

The temper color index will help you see the subtle differences between colors such as bronze and dark brown. Notice the bands of color that have appeared in this area.

The colors on the steel will be matched with a corresponding temperature during the tempering step.

Temper Color Index Chart

Many different kinds of tools can be made from the same bar of metal. The variable is the heat at which the metal is tempered. Each tool needs a different final degree of hardness, and that is accomplished by heating it to one of these temperatures, thus relaxing the brittleness just enough to make the tool hard enough to do the job, but not so hard that it will shatter when used.

Temper Color	Degrees Fahrenheit	Tool Being Made
Greenish blue	630	Light springs
	620	
Light blue	610	Screwdrivers
	600	Wood saws and punches
Dark blue	590	Springs
	580	Picks
Blue	570	Light-work cold chisels
	560	Knives
Dark purple	550	Steel cold chisels
Purple	540	Axes and center punches
Light purple	530	Hammers and sledges
Brown with purple spots	520	Surgical instruments
Dark brown	510	Twist drills
Bronze	500	Rock drills and hot chisels
Dark straw	490	Wood chisels
Golden straw	480	Drifts and leather dies
Straw	470	Penknives
Straw yellow	460	Thread-cutting tools
Yellow	450	Planer tools
Light yellow	440	Drills for stone
	430	Paper cutters and lathe tools
Pale yellow	420	Razors
	410	Burnishers
	400	Scrapers

Making a Temper Color Index

Making a temper color index will help you decide when a metal has reached the desired temperature.

Step 1—Saw a piece of flat steel about 5 to 6 inches long.

Step 2—Sand or file one side of the bar until it is bright and shiny.

Step 3—Firmly clamp one end of the steel in a pair of locking-jaw pliers, leaving 4 inches free.

Step 4—Have an adult light the propane torch.

Step 5—Place the steel over the flame, letting the light blue cone of heat touch the steel about 2 inches from the tip of the pliers.

Step 6—Continue to hold the steel over the flame in the same place. Do not wave the steel bar over the flame. Wait for the iridescent colors to appear.

Step 7—As the colors appear, continue to heat that spot and watch the colors move down the bar. The first color that will appear is a faint straw color. Soon other colors will appear, such as deeper shades of straw, bronze, purple, royal blue, and sky blue.

Step 8—When the straw color reaches about $1/16$ inch from the far end of the steel, quickly plunge the steel into a bucket of water to cool it. This is called quenching. Practice good technique by dunking the steel up and down rather than stirring it.

Step 9—When air bubbles and steam stop rising from the metal, wait about 30 seconds, then remove the piece from the water, dry it off, and rub a small amount of lubricating oil on it to protect it from rust.

Making a Center Punch

Center punch

Your first exercise in tempering will be to make a center punch, which is a basic metalworking tool used to put small dents in metal. Unless your counselor suggests another type, use a medium-carbon C1065 steel. The basic technique is the same, regardless of which steel or quenching medium is chosen.

Step 1—Measure about 6 inches of C1065 bar steel (either round or square), and mark it with a soapstone pencil.

Step 2—Position the cutting line near the edge of the vise. Clamp the jaws tightly to prevent the metal bar from vibrating as it is sawed.

Step 3—Using a hacksaw, cut the piece from the bar.

Do not scrub the file back and forth; this dulls the teeth.

Step 4—Set the bar stock aside and clamp the cut-off section in the vise with one end extending about 2 inches.

Step 5—Using a flat file, file a short tapered point in one end by bearing down on the forward stroke to scrape the metal. Lift the file away from the metal on the backward stroke.

Tempering the Center Punch

Now you are ready to temper the center punch. For safety, be sure to work under direct adult supervision.

Step 1—Using tongs, hold the center punch under a large torch flame or place it in a blacksmith's fire. Bring the metal up to a bright cherry red heat (about 1350 degrees).

Step 2—Using tongs, remove the center punch from the heat and plunge it immediately into a nearby bucket of water. Do not throw it into the water. Hold it with the tongs and dunk it up and down in the water. Do not use a swirling motion. Doing so will part the water and prevent it from completely reaching all surfaces of the steel, causing uneven cooling and warping. By moving the hot steel up and down in the water, the gas jacket that forms around it as the water turns to steam is broken up.

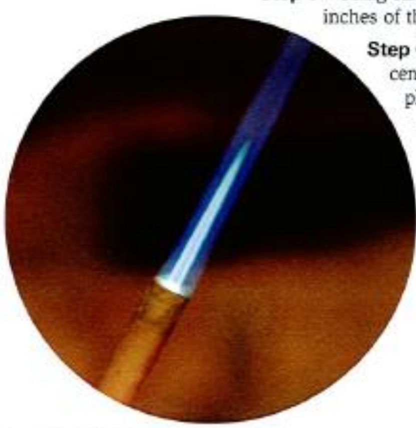
Step 3—Once the steel is cool, test it for hardness. Do not drop it or tap on it with a hammer, or it will shatter. Run an old file over the steel. (This test will dull a new file's teeth.) The steel will be so hard that it is unscratchable, or glass hard.

Step 4—Next, look at the temper color index chart and decide which temper color to use. Cross-match the colors on the chart with the color on the temper color index. You will look for that color when you heat the center punch.

Step 5—Using sandpaper, rub the last 3 to 4 inches of the center punch to a bright shine.

Step 6—Clamp the striking end of the center punch in a pair of locking-jaw pliers, leaving the pointed end free.

Step 7—Have an adult light a propane torch and hold it or set it in a secure cradle.



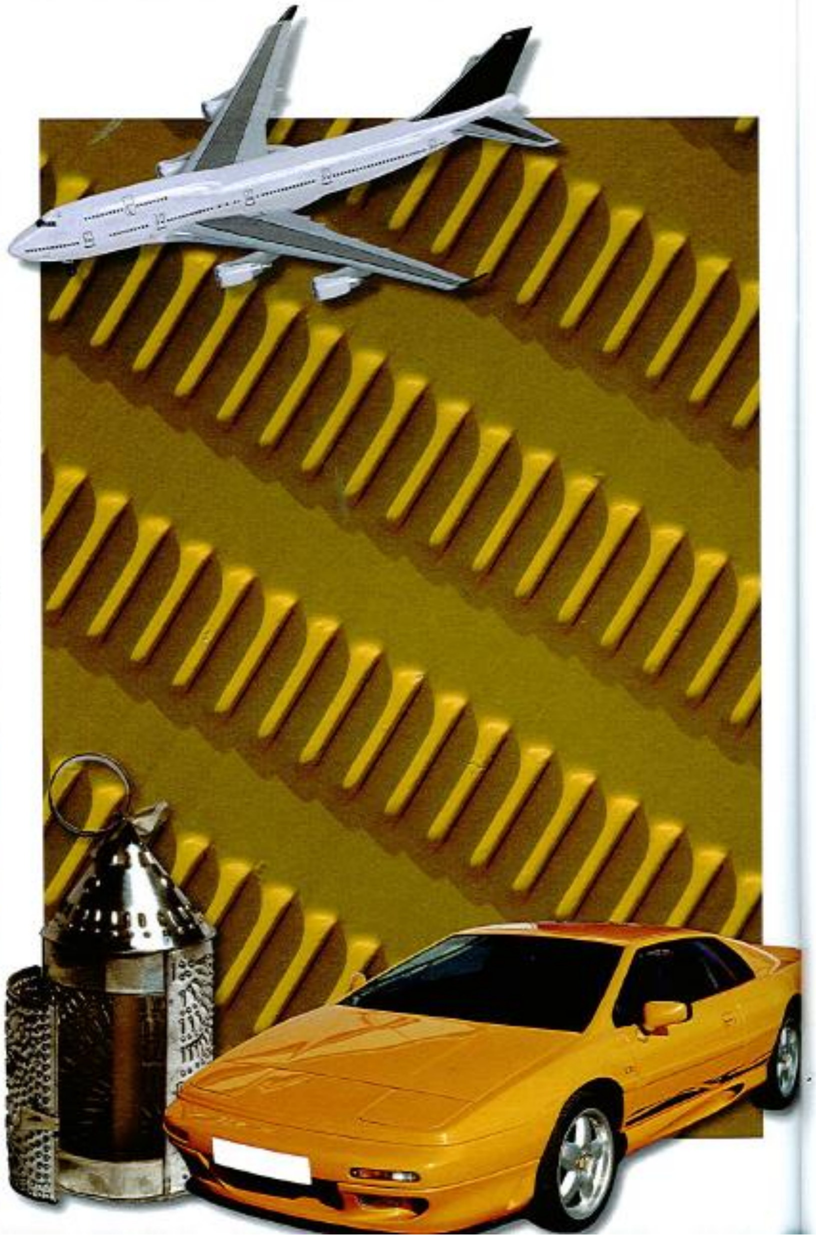
Step 8—Place the shaft of the center punch over the flame, letting the light blue cone of heat touch the steel about 2 inches from the tip of the pliers. Do not wave it over the flame.

Step 9—Wait for the iridescent colors to appear. The first color that will appear is a faint straw color. As the colors move down the bar, shades of straw, bronze, purple, royal blue, and sky blue will appear.

Step 10—When the temper color that you have chosen is about 1/16 inch from the point of the center punch, quickly plunge the center punch into a bucket of water. Remember to dunk the center punch up and down to break up the steam jacket.

Step 11—When the steel has cooled in the bucket of water for a couple of minutes, remove it from the water, dry it off, and then rub a small amount of lubricating oil on it to protect it from rust.

If the steel is quenched at the wrong time, the entire tempering process must be repeated. Being able to judge the precise time to quench the steel takes practice.



The Sheet Metal Mechanic/Tinsmith

The difference between a sheet metal mechanic and a tinsmith is the metal that they use. For the most part, all metalworkers use the same techniques.

Today, people who work with sheet metal are called sheet metal mechanics because they are trained to work with any type of sheet metal. Working with thin sheets of stainless steel, aluminum, mild steel, galvanized steel, copper, and brass, a sheet metal mechanic can make a remarkable range of items.

Using many of the traditional tinsmith's skills along with more modern techniques such as spot welding, sheet metal mechanics make a wide range of components used in things like automobiles, aircraft, satellites, heating and air-conditioning systems, building construction, and consumer products. Because maintaining high rates of productivity is so important to manufacturing, sheet metal mechanics use machine tools to assist them when they roll, cut, and bend each item's basic components.

Not all sheet metal mechanics work in manufacturing plants. Many work in local shops that fabricate components for heating and air-conditioning systems. Some make custom-designed components for local building construction firms.

Many of today's tinsmiths are trying to preserve the craft. Working with tools of ancient design, they use sheets of tin-plated steel to fashion museum reproductions for collectors and historic re-enactors. Sheets of pure tin were used to make household objects until the 18th century, but today the sheets are expensive and rare.

Basic Sheet Metalworking Tools

The tools needed by the sheet metal mechanic/tinsmith are not much different from the basic metalworking tools you learned about in the previous chapter. However, a few of these tools have special duties in the sheet metal mechanic's shop.

Anvils

Stake anvil

Some of the most basic metalworking tools, *anvils* are the large blocks of iron on which pieces of metal are shaped. There are several types of anvils, and stake anvils are some of the most common.

Stake anvils are designed to be moved easily. They are usually mounted in a metal stake holder that has been attached to a stump or a large block of wood. A stake anvil does not need to be as heavy as a blacksmith's anvil because sheet metal is bent rather than forged.

The tinner's anvil has a flat surface with one curved edge. It is used to make straight and curved bends in thin sheets of tin-plated steel. It can be held in the square (*hardie*) hole of a blacksmith's anvil. The curved sides of the canister stake are useful when turning up the flatlock seam that is used when a capped bottom is attached to a canister or a drinking cup. The widely flared horn of a funnel stake is used to roll tapered cylinders such as a funnel.

The hatchet stake is used for making bends that go past 90 degrees. This is the stake used to put the bends in a flatlock seam. A hatchet stake can be made from a piece of $^{3}/_{4}$-inch-thick hardwood, such as maple or ash, that is cut to a 45-degree edge on one side. It can be clamped in a vise and used horizontally or it can be placed on its side on the edge of a worktable with the long side down. Either way it is held, the sheet metal is tapped back against the angled face to form the flatlock seam.

Hammers

Tinner's hammer

The face of a tinner's hammer is used to set rivets. The tapered end—the peen—is used to coax sheet metal around bits of stiff wire when making a wire edge. The bordering hammer also can be used in more advanced techniques to coax the sheet metal around a wire when making a wired edge and to bend the flatlock seam around the bottom of a canister when making a capped bottom.

Hand Shears

Hand shears

Simple hand shears will work for all of the projects described in this pamphlet. Professional sheet metal mechanics and tinsmiths often use large, foot-operated shears or power-operated shears to cut their pieces from large sheets, but using hand shears is best for learning basic metalworking techniques. Only adults should use these power tools.

Make sure to keep hand shears sharp and well-maintained. Never try to cut thick sheets of metal with hand shears—this will dull the cutting edges and can cause the pivot bolt in the jaw to break. When you are done using the shears, wipe them with a clean cloth to remove the hand oils that cause rust. Be sure to place a light coat of oil on the shears and then wrap them in an oil-soaked cloth to prevent them from rusting. This is a good practice with all steel tools.

Preserving Your Work

Most finished metal pieces will need to be treated against rust and other forms of *oxidation*, which will ruin the piece over time. Objects made from zinc-plated (galvanized) metal need no further treatment to prevent rust because the zinc coating is the preservative. Aluminum does oxidize, turning white and chalky. Zinc chromate primer must be applied before painting aluminum or the paint will flake off.

Those who prefer a shiny metal surface must apply a degreaser to the metal and then apply a good quality clear-coat sealer. Clear polymer-based varnishes are often used. Tin-plated steel need not be painted because the tin coating acts as the preservative. Because the tin coating is so thin, it must be washed and dried after handling to remove natural salts and acids left by human hands.

Copper, brass, and bronze also oxidize, turning green. Some people like this green effect and encourage the oxidation process by applying salt water to the piece.

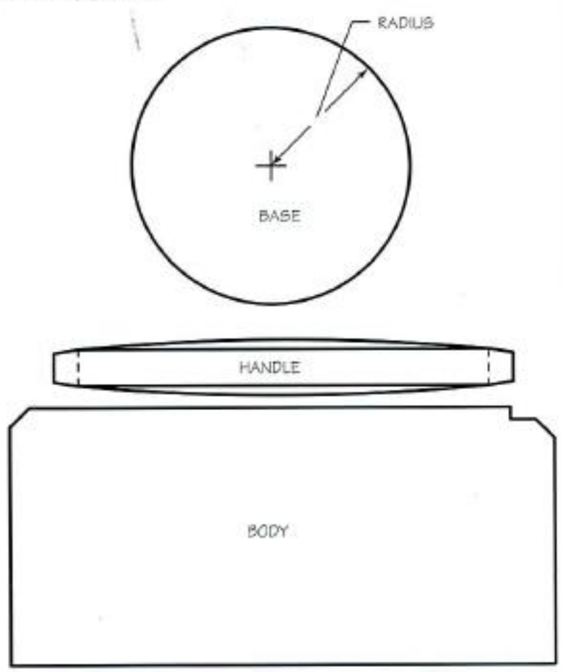
Sheet Metal Projects

The sheet metal projects described in this pamphlet create simple objects that can be useful in camp. If you have an idea for a project that is not described here, you may design your own. Be sure your design uses some of the basic metalworking techniques described earlier.

Regardless of whether you have decided to make practical objects or art objects, be sure to show your design sketches to your counselor and to obtain your counselor's permission before you begin working on your projects.

Making a 16-Ounce Metal Cup

Metal cup patterns

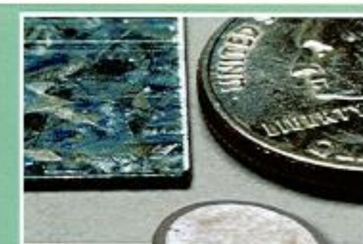


Basic Tools Needed

- ❑ Bick iron stake
- ❑ Hatchet stake (can also be made of hardwood with one edge cut to a 45-degree bevel)
- ❑ Funnel or canister stake (optional)
- ❑ Stake holder
- ❑ Short length of 3-inch-diameter iron pipe
- ❑ Mallets
- ❑ Sturdy machinist's vise
- ❑ Sheet metal shears
- ❑ 1-inch hole punch
- ❑ Stump (for mounting the stake holder)
- ❑ 125-watt or 150-watt soldering iron
- ❑ C-clamps
- ❑ 2-by-4-inch wood pieces in various lengths
- ❑ Center punch
- ❑ Steel ruler
- ❑ Hemmer
- ❑ Hand seamer
- ❑ Scriber
- ❑ Steel dividers
- ❑ Try square
- ❑ Needle-nose, lineman's, and locking-grip pliers
- ❑ Various patterns
- ❑ Flux brushes
- ❑ Shop apron
- ❑ Leather gloves
- ❑ Safety glasses

Materials

- ❑ 26-gauge or 28-gauge sheet metal
- ❑ Lead-free solder
- ❑ Soldering flux
- ❑ Wire coat hanger
- ❑ Finishing nail (to prick pierced patterns in sheet metal)
- ❑ ¼-inch copper tubing
- ❑ Three 4-by-6-inch pieces of window glass (¼ inch thick) per lantern



Step 1—Using the drawings as an example, sketch patterns on stiff paper for each of the three cup pieces: the body, the handle, and the base. When you have your sketches how you want them, cut out the shapes. These are your template pieces.

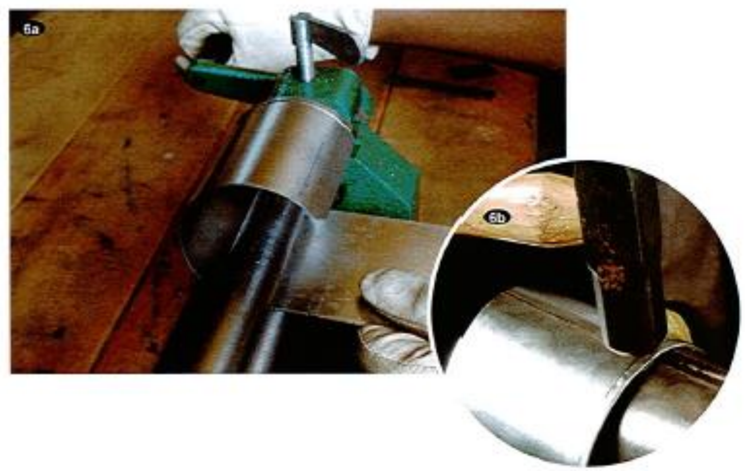
Step 2—Arrange the template pieces on the sheet metal and use a sharp nail or metal scriber to trace the outlines onto the tinplate.

Step 3—Using sheet metal shears, follow the scribed lines to cut out the three pieces. Use construction scissors to snip the ¹⁄₁₆-inch nicks in the pieces to be used as the cup's body and handle.

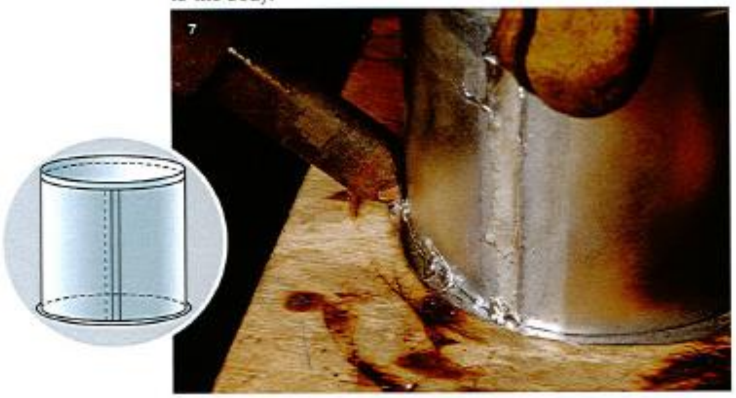
Step 4—Once the pieces are created, you can start putting together the body of the cup. Start by creating a safe edge along the top of the cup by bending over about ¼ inch of the tin.

Step 5—Bend the flatlock seam edges on both ends of the body, but don't attach the seam yet.

Step 6—Roll the cup body into a cylinder, then attach the flatlock seams.



Step 7—Solder the flatlock seam, then solder the bottom piece to the body.

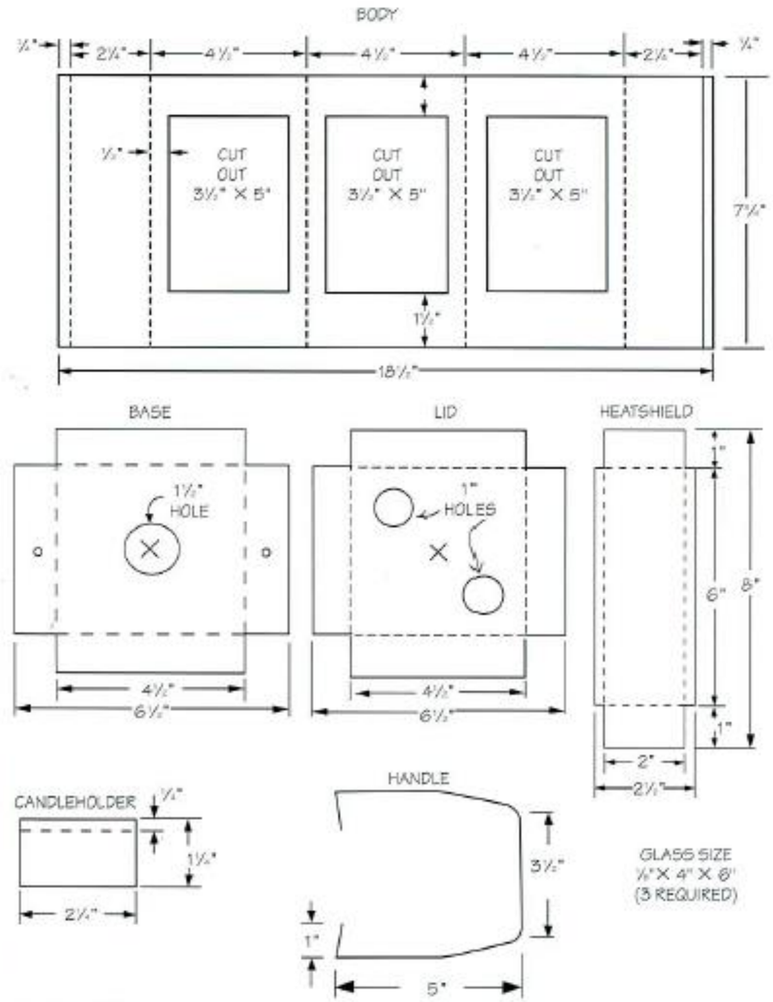


Step 8—Now you are ready to create the handle. Begin by folding safe edges along both sides just as you did the lip of the cup in Step 4, then roll the handle piece into a curve. Lastly, bend over about ¼ inch of each end to make "ears" to attach the handle to the body.

Step 9—Finish the cup by soldering the handle to the body.

Step 10—Fill the cup with water to check for leaks.

Making a Lantern

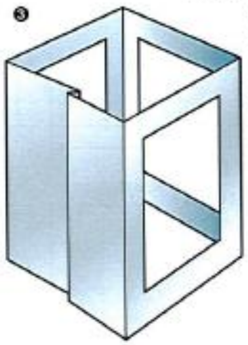


Lantern pattern

Step 1—Arrange the patterns on a piece of sheet metal and scribe the outlines onto the sheet metal with a sharp nail or a metal scriber. Cut out each component using sheet metal shears and file all edges smooth.

Step 2—Punch a large hole in the center of the parts marked "cut out" in the pattern diagram; these parts will become the windows. Stick the tip of the snips into the hole and carefully cut a curved line until you reach one of the scribed lines that outline the shape of the window. Now you can cut straight along the scribed line.

3



Step 3—Fold the lantern body's ¼-inch bends first, making sure to fold them in opposite directions. Next make the four body folds.

Step 4—Fold a hem on the candleholder and flatten it slightly with a mallet. Roll the candleholder into a cylinder around a ¾-inch dowel. Don't try to close the gap in the cylinder—it comes in handy when removing melted candle stubs. You can use the blade of a screwdriver to pry out the melted wax.

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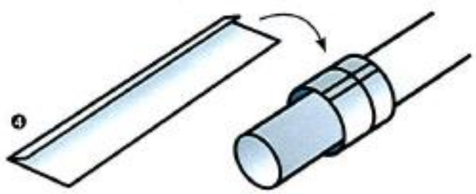

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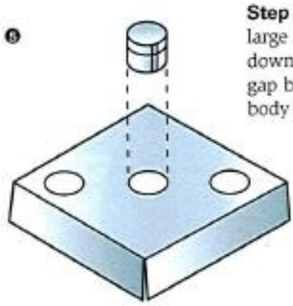

Step 5—Create the bottom piece by punching two large air holes in the base as shown and then folding down all four sides. Don't worry about leaving a small gap between each fold because this piece fits inside the body of the lantern. Solder the candleholder in place.

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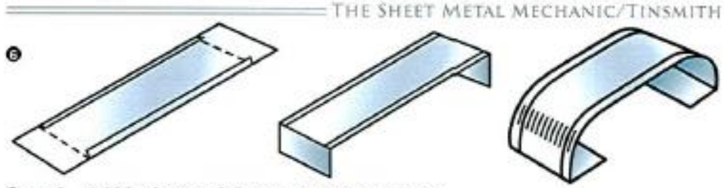

Step 6—Fold both ¼-inch hems on the heat shield component. Fold the tabs as shown. Roll the heat shield into a flat-topped arc.

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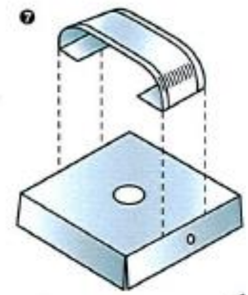
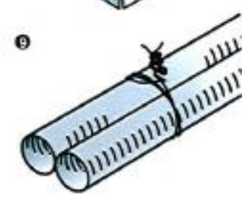


Step 7—Create the top piece by punching a large air hole in the center of the piece. Punch two small holes in an opposite pair of tabs for the wire handle. Fold down the sides—don't worry about leaving a small gap because this piece fits over the lantern body. Solder the heat shield into place.

Step 8—Set the body of the lantern over the bottom piece and solder the bottom in place.

Step 9—Make the glass holders by cutting pieces of ¼-inch copper tubing to fit inside the lantern. Cut two lengths of tubing for each corner. Use florist's wire to wire them together in pairs, then solder them together. Remove the wires.

9



Step 10—Use a wire coat hanger to make the handle. Cut off the hook and straighten the length of wire, then bend it into the shape of a handle.

Step 11—Set the top on the body (it fits on the outside). Poke the scriber through the holes in the top and mark the corresponding spot on the body.

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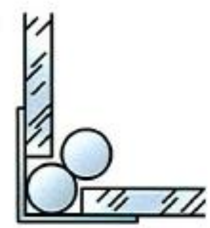
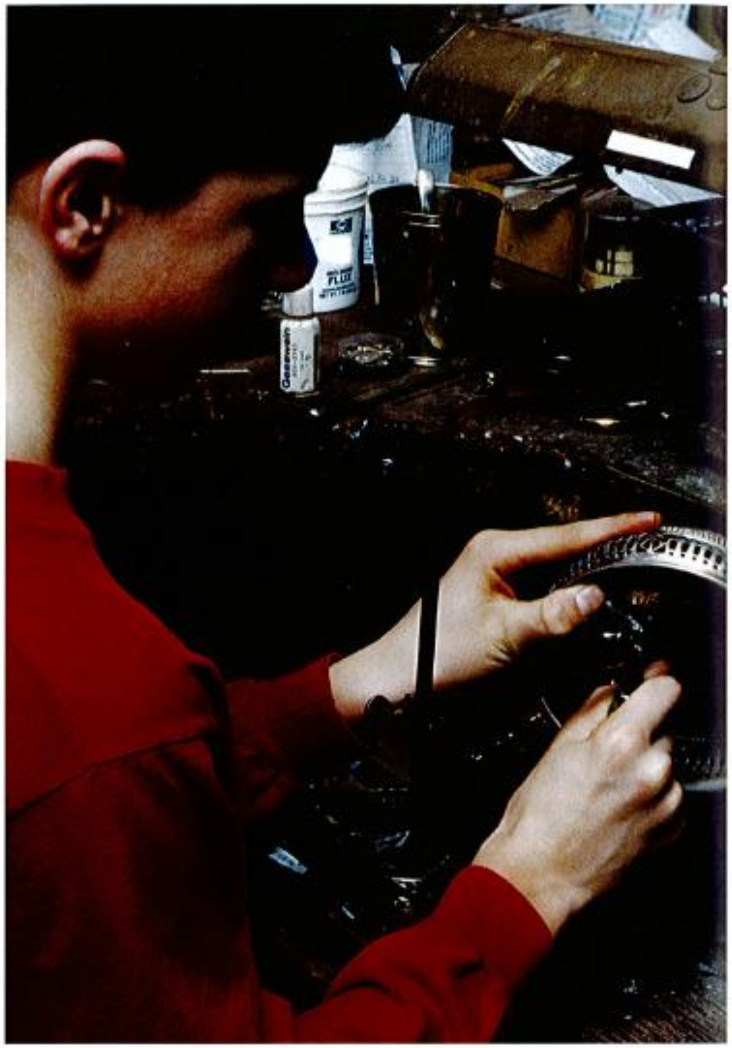


Step 12—Remove the top piece and use a nail to punch holes where you just marked.

Step 13—Have an adult cut three 4-by-6-inch pieces of ¼-inch window glass. Put them in the lantern body and hold them in place using the copper glass holders.

Step 14—Place a candle in the lantern and attach the top using the wire handle.

To replace the candle, unhook the wire handle and remove the top piece.



The Silversmith

Silversmiths do much more than hammer silver into beautiful shapes. They are artists who design one-of-a-kind pieces that start as a sheet of silver, often incorporating elegant hand engraving and beautiful patterns. They are also highly skilled in a number of metal-working techniques.

Well-trained silversmiths know how to function as sheet metal mechanics. They cut, bend, edge, roll, file, saw, rivet, solder, and braze, using sheets of silver, copper, nickel silver, and pewter. Silversmiths are pattern makers and founders. They carve their own intricate patterns, create the molds, melt the silver, and then pour it into the molds. Silversmiths know the craft of the blacksmith. They know how to forge and temper high-carbon steel to make their own engraving tools, chasing tools, hammers, and stake anvils.

Silversmiths are practical metallurgists who understand the properties of the metals they use. They know when to anneal a work-hardened piece and how to use work hardening to their advantage.

Planishing is the process of smoothing the finished piece, so hammers used in this process must be fairly specialized to do the job. Some planishing hammers have both a round face and a square face. The square face is helpful for working with the corners of rectangular pieces. One of the final steps in silversmithing, planishing work-hardens the metal while giving its surface a much more uniform appearance.

Basic Silversmithing Tools

Silversmiths use many of the same tools as other craftsmen, but because the objects silversmiths create are smaller, their tools are scaled accordingly.

Hammers

The hammers used by silversmiths have specific shapes that have been refined over thousands of years to perform specific purposes. Each hammer's face has a slightly different curve.

Raising hammers and forming hammers are used for making curved shapes. A *planishing* hammer is used to remove dents made by other hammers during the raising and forming stages. Forging hammers are used to fashion an object from thick material. Because forks, spoons, and ladles, for example, are often made from heavy-gauge metal, forging them requires a much heavier hammer. Forging hammers usually weigh 18 to 24 ounces.


Raising hammer


Planishing hammer

Hammers and stakes have smooth, highly polished surfaces. Great care must be taken not to mar the surfaces of these tools because any defect will transfer to the silver as you hammer it.

Rub the tools on a piece of cloth to burnish them before use. After using these tools, wipe the steel surfaces with a clean, lubricated cloth. Wrap the head of the hammer in an oil-soaked cloth for storage. These steps are especially important to help prevent rust and for long-term storage.

Mallets

Like the other metalworkers, silversmiths use mallets to bend sheet silver. Made of rawhide, hardwood, plastic, or nylon, these soft-faced mallets are less likely to mar the surface of the metal than a metal hammer. Some silversmiths glue leather to the faces of their wooden raising mallets to cushion blows even more. Mallets are used to true up, or straighten, pieces that have become warped or bent during *sinking* or raising steps.


Flat-faced wooden mallet

Stakes and Anvils

Silversmiths use some of the same stakes and anvils as sheet metal mechanics and tinsmiths, such as the bottom stake and the ball stake. Some stakes silversmiths use look the same as other craftsmen's tools but are much smaller in scale. In other cases, some of the silversmith's stake anvils are uniquely different.

The raising stake is an example of a stake that is uniquely the silversmith's. Used with a raising hammer (a hammer with a head that has a similar curve to the desired curve), the raising stake is used to curve flat sheets of metal. Water pitchers, bowls, and flower vases, for example, start off as flat disks of silver, and the raising stake or hammer lifts—or raises—the metal to form the shape.

A silversmith's anvil is kept highly polished and unmarred. To keep an anvil "perfect," take care to avoid striking it with a hammer when working a bend or curve in a project.


Jeweler's anvil